BEST MANAGEMENT PRACTICES FOR URBAN STORMWATER RUNOFF

New Hampshire Department of Environmental Services
Water Supply and Pollution Control Division

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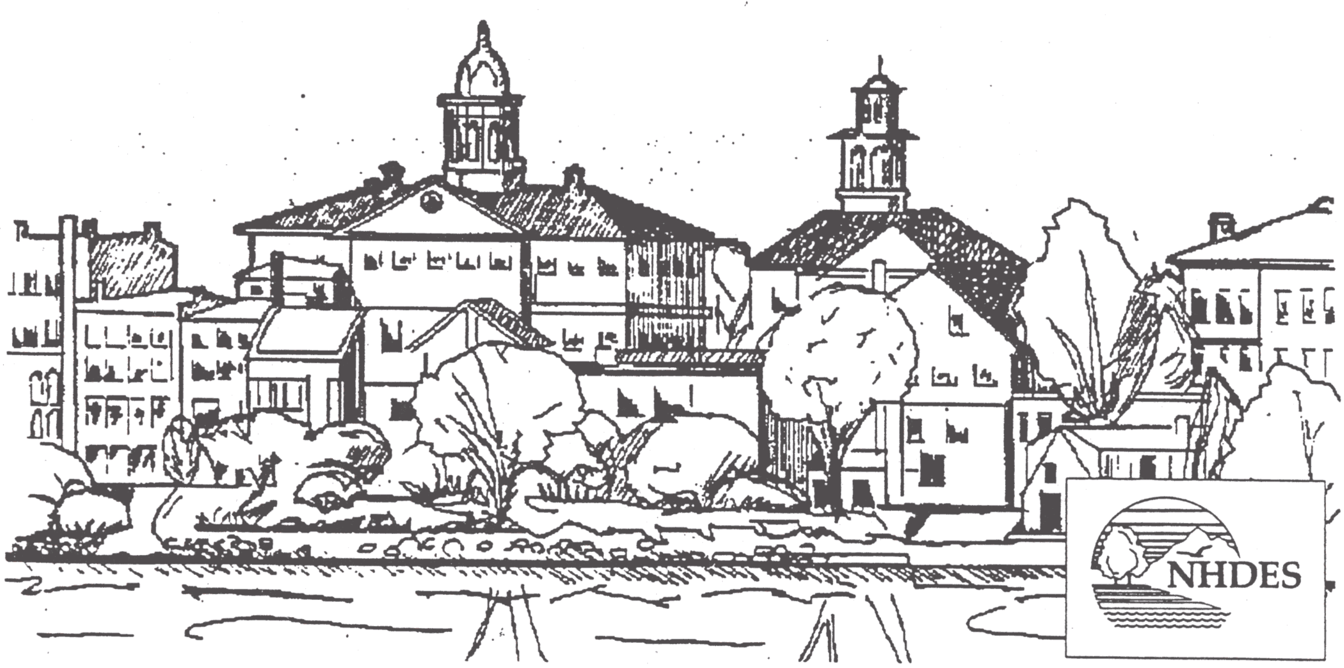

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BEST MANAGEMENT PRACTICES
FOR
URBAN STORMWATER RUNOFF

JANUARY 1996

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THE IMPACTS OF URBAN RUNOFF

CHAPTER 1: THE IMPACTS OF URBAN RUNOFF

INTRODUCTION

Urbanization can significantly impact surface waters by several mechanisms:

- As an area becomes urbanized, natural, pervious areas are typically covered with pavement, buildings and less pervious landscaped areas. This reduces the amount of rainfall infiltration to the groundwater and increases the amount of stormwater runoff. In addition, drainage improvements constructed during urbanization decrease the travel time of stormwater runoff. The result is that the peak stormwater discharge from the urbanized area is increased, and the low stream flow normally associated with shallow groundwater flow is decreased. Therefore the result of urbanization is higher stream flows during periods of rainfall and lower stream flows during dry periods.

- A second impact which is related to the changes in hydrology discussed above is streambank erosion caused by an increase in peak runoff. In order for a stream channel to accommodate the increase in peak flow it must erode a larger channel. The material from this enlargement becomes part of the bed load of the stream, taking many years to work its way downstream. This eroded material causes the same problems as sediments from other sources.

- A third major impact of urbanization is the long term impacts on water quality as a result of urban runoff. Urban development causes an increase in the pollutants in stormwater. These pollutants can vary widely from event to event and over the course of the year. These pollutants are a normal byproduct of modern urban life and include such pollutants as road salt, fertilizers, pesticides, heavy metals, oils, nutrients, oxygen-demanding substances, and bacteria.

WATER QUALITY IMPACTS OF URBAN RUNOFF

There are several mechanisms for depositing pollutants on the urban landscape. These include dryfall and wetfall of atmospheric pollutants; direct application of such materials as road salt and sand, fertilizers and pesticides; and applications which are unintentional but a normal result of urban activity, such as oil drippings from motor vehicles.

Pollutants are also picked up from the various surfaces in the urban environment. Trace metals are picked up from metal roofing and flashing, metal culverts, paints, and automobile products. As these materials age and corrode, some of the metals are released to the environment (Schueler, 1987).

Additional sources of pollutants include pet droppings, vegetative matter, litter and anything else deposited upon the urban landscape and capable of being washed off. These pollutants are picked up by runoff and carried along until the runoff reaches a water body.

The Rhode Island Department of Environmental Management, (1993) lists the following pollutant concentrations in urban runoff:

POLLUTANT (mg/l)	RESIDENTIAL[a]	COMMERCIAL[a]	INDUSTRIAL[a]	URBAN HIGHWAY[b]	RURAL HIGHWAY[b]	UNDEVELOPED
Total Phosphorus	0.620	0.290	0.420	0.491	0.209	0.061
Total Nitrogen	2.030	2.300	2.530	3.180	1.737	1.355
Copper	0.056	0.050	0.032	0.066	0.029	--
Lead	0.293	0.203	0.115	0.491	0.105	0.020
Zinc	0.254	0.418	1.063	0.404	0.105	0.081
TSS	228.0	169.0	108.0	174.2	53.5	--
BOD	13.0	14.0	10.0	--	--	--
COD	102.0	84.0	62.0	139.8	64.0	--

[a] Source: Whalen and Cullum, 1989
[b] Source USDOT, 1990 (urban highway >30,000 vehicles/day and rural highway < 30,000 vehicles/day)
[c] Source: Oakland et al., 1983 (copper data is suspect and atypical, therefore not reported)

A study in Maine documented the elevated levels of phosphorus export from developed watersheds. In adjacent watersheds, one developed and one undisturbed, phosphorus export from the developed watershed was up to ten times greater than from the forested watershed (Maine Department of Environmental Protection. 1989) This corresponds quite well with the Rhode Island Department of Environmental Management information.

Schueler, (1987) developed an empirical method. known as the Simple Method, for estimating pollutant export from urban development sites The table below is similar to one published by the Metropolitan Washington Council of Governments, but is based upon the National Urban Runoff Program (NURP) national average data.

Annual Storm Pollutant Export (Pounds/Acre) for Selected Values of Impervious Cover (I) Developed from the Simple Method[1,2] are as follows:

LAND[3] USE	SITE IMPERVIOUSNESS %	TOTAL PHOSPHORUS	TOTAL NITROGEN	BOD 5-DAY	ZINC[4]	LEAD[4]
RURAL RESIDENTIAL	0	0.19	1.35	4.86	0.07	0.07
	5	0.36	2.57	9.22	0.14	0.14
	10	0.53	3.78	13.59	0.20	0.21
LARGE LOT SINGLE FAMILY	10	0.53	3.78	13.59	0.20	0.21
	15	0.69	5.00	17.96	0.27	0.27
	20	0.86	6.21	22.33	0.33	0.34
MEDIUM DENSITY SINGLE FAMILY	20	0.86	6.21	22.33	0.33	0.34
	25	1.03	7.43	26.70	0.39	0.40
	30	1.20	8.64	31.07	0.46	0.47
	35	1.37	9.86	35.44	0.52	0.54
TOWNHOUSE	35	1.37	9.86	35.44	0.52	0.54
	40	1.54	11.07	39.81	0.59	0.60
	45	1.71	12.29	44.18	0.65	0.67
	50	1.88	13.50	48.55	0.72	0.73
GARDEN APARTMENT	50	1.88	13.50	48.55	0.72	0.73
	55	2.05	14.72	52.92	0.78	0.80
	60	2.21	15.94	57.29	0.85	0.87
HIGH RISE LIGHT COMMERCIAL/ INDUSTRIAL	60	2.21	15.94	57.29	0.85	0.87
	65	2.38	17.15	61.66	0.91	0.93
	70	2.55	18.37	66.03	0.98	1.00
	75	2.72	19.58	70.40	1.04	1.06
	80	2.89	20.80	74.77	1.11	1.13
HEAVY COMMERCIAL, SHOPPING CENTER	80	2.89	20.80	74.77	1.11	1.13
	85	3.06	22.01	79.14	1.17	1.20
	90	3.23	23.23	83.51	1.24	1.26
	95	3.40	24.44	87.88	1.30	1.33
	100	3.57	25.66	92.25	1.36	1.40

[1] P(rainfall depth)=40 inches, Pj(runoff correction factor for storms that produce no runoff)=0.9, Rv(runoff coefficient)=0.05+0.009(I), I=% site imperviousness, C(mean concentration of pollutant)=NURP National Average Values, A(area)=1 acre.

[2] These values are based on NURP national average values and may not be applicable to all situations

[3] Rural Residential: 0.25-0.50 Dwelling Units (DU)/acre
Large Lot Single Family: 1.0-1.5 DU/acre
Medium Density Single Family: 2-10 DU/acre
Townhouse and Garden Apartment: 10-20 DU/acre

[4] Extractable

IMPACTS OF SPECIFIC POLLUTANTS

Sediment. Suspended sediments constitute the largest mass of pollutant loadings to surface waters (United States Environmental Protection Agency, 1993). Sediment causes an increase in turbidity and a decrease in light penetration and resultant impairment of photosynthesis of aquatic plants. It can smother benthic life; impair the respiration of fish and aquatic invertebrates. Sediment deposits in shallow areas of lakes and ponds can provide a suitable substrate for aquatic plant colonization. Sediment can carry significant quantities of nutrients; and can significantly decrease recreational values (United States Environmental Protection Agency, 1993; Schueler, 1987; New York Department of Environmental Conservation, 1992).

The primary source of sediment in urban runoff is construction related. However, sediment also results from increased streambank erosion; winter sanding of roadways; erosion of high traffic areas of unpaved urban surfaces, and natural soil erosion.

Nutrients. Nutrients (particularly phosphorus) can have a dramatic impact upon freshwater lakes and ponds. Phosphorus is the limiting nutrient for most lakes and ponds and an increase in phosphorus can cause a corresponding increase in algae. Algae are microscopic plants which are common in our lakes, with the addition of excess phosphorus their populations can increase rapidly. In a worse case, the algae populations may soar causing an algae bloom, discolor the lake water, and cause odors as the algae die and decay. Algae growth can also lead to the lowering of a lake's oxygen supply, and the elimination of certain species of fish. High nitrogen loadings can lead to similar problems in coastal areas.

Urbanization changes the natural landscape, which normally would retain most of the nutrients falling on it. Land disturbance upsets the environment's ability to retain phosphorus. Stormwater flowing over the land surface picks up phosphorus and transports it either in soluble form or attached to soil particles. The phosphorus is from numerous sources both natural and human and includes eroded soil, road dust, plants, fertilizers and detergents (Maine Department of Environmental Protection, 1989).

Nitrogen, like phosphorus, is very common in the natural environment. There are many sources of nitrogen including animal waste and decaying plants and animals. The urban landscape being largely impervious, the opportunity for the removal of nitrogen from stormwater is limited.

Oxygen-Demanding Substances. Organic matter which falls on, and accumulates on the landscape is washed off during runoff events. This organic matter utilizes oxygen in its decomposition. This oxygen utilization places an oxygen demand on the receiving water body. BOD levels in urban runoff can exceed 10 to 20 mg/l during storm "pulses" which can lead to anoxic conditions (zero oxygen) in shallow, slow-moving or poorly-flushed receiving waters (Schueler, 1987). The NURP study found that oxygen-demanding substances can be present in urban runoff at concentrations similar to secondary wastewater treatment discharges (United States Environmental Protection Agency, 1993).

The greatest export of BOD occurs from older, highly impervious residential areas with outdated combined storm sewers and large populations of pets. In contrast, only moderate BOD export has been reported from newer, low density suburban residential development (Schueler, 1987).

Trace Metals. Trace or heavy metals are typically found in urban runoff. These metals are important due to their potentially toxic effects upon aquatic life and the potential to bioaccumulate in fish and shellfish (United States Environmental Protection Agency, 1993). The most prevalent metals in urban runoff are copper, lead and zinc (United States Environmental Protection Agency, 1993; Schueler, 1987).

A large portion of trace metals are attached to sediment. This means that they are not immediately available for biological uptake and the metals associated with sediments, are easily removed by sedimentation (Schueler, 1987).

Other Pollutants of Concern. Urban runoff will contain bacteria levels which frequently exceed public health standards (Schueler, 1987); oils and grease from motor vehicles and other similar sources; toxic chemicals from a variety of sources; and road salt used in deicing. Lastly, urban runoff can be a source of thermal pollution. Rainfall falling on roofs and pavement which have been heated by the sun will be heated by these surfaces. The elevated temperature of this runoff can be stressful or even lethal to certain aquatic organisms (Schueler, 1987; New York Department of Environmental Conservation, 1992).

The United States Environmental Protection Agency (1993) presents the following general table of sources of urban runoff pollutants:

Source	Pollutants of Concern
Erosion	Sediment and attached soil nutrients, organic matter, and other adsorbed pollutants
Atmospheric deposition	Hydrocarbons emitted from automobiles, dust, aromatic hydrocarbons, metals, and other chemicals released from industrial and commercial activities
Construction materials	Metals from flashing and shingles, gutters and downspouts, galvanized pipes and metal plating, paint, and wood

Sources of Urban Runoff Pollutants (Continued)

Source	Pollutants of Concern
Manufactured products	Heavy metals, halogenated aliphatics, phthalate esters, polynuclear aromatic hydrocarbons, and pesticides and phenols from automobile use, pesticide use, industrial use, and other uses
Plants and animals	Plant debris and animal excrement
Non-stormwater connections	Inadvertent or deliberate discharges of sanitary sewage and industrial wastewater to storm drainage systems
Onsite disposal systems	Nutrients and pathogens from failing or improperly sited systems

As neighborhoods age their urban runoff tends to have significantly higher pollutant concentrations. Older neighborhoods tend to become less pervious over time with additional building activity, driveways, decks, patios, and the general compaction of the pervious areas. As trees mature in these areas the underlying grassed areas tend to die off, leaving bare earth. The pollen and leaf fall from these trees, which would be retained on a forest floor in a natural area, is now washed off with the runoff (Schueler. 1987)

SUMMARY

Rainfall and runoff are natural occurrences in our environment. The urbanization of the landscape however, can have significant impacts upon runoff. This chapter together with Chapter 2 discuss the impacts upon the environment by urbanization. The remaining chapters will discuss the various measures available to mitigate these impacts. These measures are numerous and the needs of the development and its watershed will often dictate which measures to use.

As a general rule, the less the concentration of runoff, and the less sophisticated the treatment measure, the better the solution. Natural solutions are preferred over constructed solutions, i.e., buffer strips are preferred to water quality inlets. However, it is recognized that certain developments in highly urbanized areas do not have sufficient land area for natural treatment methods.

Proper planning of the development is important as it has been shown that the directly connected impervious areas are the most critical to the quantity, rate and pollutant concentration of the runoff. Proper planning can allow for landscaping which incorporates areas for shallow ponding, and infiltration, overland flow through vegetated areas, and minimizes directly connected impervious areas. In areas requiring stormwater detention for peak flow reduction it is frequently best to combine the treatment and detention measure in one device such as an extended detention pond, wet pond, or created wetland.

Because some amount of infiltration is inherent in most stormwater treatment options the following criteria should be followed regarding siting:

- Runoff from residential and commercial properties should be diverted and treated outside the protective radius of community ("C") and non-community, non-transient ("P") public water supply wells (i.e., 200 feet from small, less than 57,600 gallons per day and 400 feet from large 57,600 gallons per day or more C and P wells).

- Runoff from industrial or petroleum storage and /or dispensing sites should be diverted and treated with a non-direct infiltration option 500 feet from a small and 1000 feet from a large C or P well (Pillsbury, 1995).

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CHAPTER 2

STORMWATER QUANTITY

CHAPTER 2: STORMWATER QUANTITY

INTRODUCTION

Urban development generally increases both the rate and total volume of stormwater runoff. When an area is urbanized, the amount of impervious surfaces is increased, which changes its response to precipitation. The increase in impervious surfaces decreases the amount of precipitation that can infiltrate and decreases the runoff travel time through the watershed.

CURRENT RESEARCH AND CONCLUSIONS

Schueler (1987), describes the following hydrological changes resulting from urbanization:

- Increase peak discharges about two to five times higher than pre-development levels (Leopold, 1968; Anderson, 1970).

- Increase in volume of storm runoff produced by each storm, in comparison to pre-development conditions. A moderately developed watershed may produce 50% more runoff volume than a forested watershed during the same storm.

- Decreased time needed for runoff to reach the stream (time of concentration) by as much as 50% (Leopold, 1968), particularly if extensive drainage improvements are made.

- Increased frequency and severity of flooding. A short, intense summer thunderstorm that had only slightly raised water levels in the past now turns the stream into a torrent. In a natural state, a stream experiences bankfull discharges (i.e., runoff entirely fills the stream channel) only about once every two years. In moderately developed watersheds, bankfull discharges may occur as often as three or four times a year.

- Reduced streamflow during prolonged periods of dry weather due to the reduced levels of infiltration in the watershed. In smaller, headwater streams, the reduction may be enough to cause a perennial stream to become seasonally dry.

- Greater runoff velocity during storms, due to the combined effect of higher peak discharges, rapid time of concentration, and smoother hydraulic surfaces that occur as a result of development.

These changes to the watershed hydrology require a consideration of three different aspects of urban hydrology:

- The potential flooding of downstream properties, and/or exceeding of the capacity of downstream drainage structures, due to the increase in peak runoff;

- The potential for streambank erosion, due to the increase in peak runoff;
- And the quantity of runoff which should receive stormwater treatment, for the removal of urban pollutants.

FLOODING

Historically the main concern of urban drainage design has been flood control. Drainage systems were designed to convey the runoff from a "design storm" off-site. This was done so that flooding of downstream properties was not a problem, and the capacity of downstream drainage structures was not exceeded, but rapid enough to prevent impacts to the property under consideration. Design storms have been based upon a 10, 25, 50, or even 100-year return frequency, i.e., storms that are uncommon.

While still of major concern, flooding is not the only concern. From a water quality perspective these large storms are not as great a concern. Most of the runoff volume, and therefore most of the mass pollutant discharges, are generated by smaller storms simply because there are many more of them.

The design storm presently used for flood control varies widely with 10, 25 and 50 year storms being very common. As discussed later, the 2-year storm event, although not usually causing flooding problems, needs to be considered in design of detention facilities to prevent streambank erosion. Another concept that must be considered is the potential cumulative impact of a series of detention facilities in an individual watershed. A detention facility low in a watershed may detain stormwater long enough to coincide with the peak discharge for the watershed at that location thus increasing the peak flow. In addition the cumulative impact of development and stormwater detention facilities on a watershed is of concern

STREAMBANK EROSION

A typical stream channel is naturally sized to flow bank full during a one or two year storm event. Urbanization of a watershed will increase the runoff from this storm event. Schueler (1987) describe the following in reference to streambank erosion effects associated with urbanization:

- The primary adjustment to the increased storm flows is through channel widening. Numerous surveys (Robinson, 1976; Fox, 1974; Hammer, 1972) and anecdotal evidence (Ragan and Dietemann, 1976) have shown that most streams widen two to four times their original size if post-development runoff is not effectively controlled. The resulting streambank erosion is severe because most floodplain soils are unconsolidated and highly erodible.
- The elevation of the stream's floodplain must increase to accommodate the higher post-

development peak discharge rate. Property and structures which had not previously been subject to flooding now may be at risk.

- Streambanks are gradually undercut and slump into the channel. Trees that had protected the banks are gradually exposed at the roots, and are more likely to be windthrown, triggering a second phase of bank erosion.

- The prodigious quantities of the sediment eroded from streambanks and upland areas are seldom completely exported from the watershed. Much of it remains as temporary channel storage as sandbars and other sediment deposits. Gradually, the extra sediment moves through the stream network as bedload. However, for many years the channel substrate is covered by shifting deposits of mud and sand.

DESIGN FOR STORMWATER TREATMENT

Research by Pitt (1993) has shown that small storms are the important ones for water quality investigations, he reached the following conclusions:

- Storms less than 0.5 inches are important for water quality standard violations, especially for bacteria

- Storms from 0.5 to 1.5 inches are responsible for most pollutant mass discharges

- Larger storms are much less common and are important in the design of conveyance systems. In addition, the runoff from these larger storms may be dominated by runoff from pervious areas.

Further:

- During the 1983 NURP monitored rain year for Milwaukee, 66 percent of all rains were less than 0.5 inches in depth

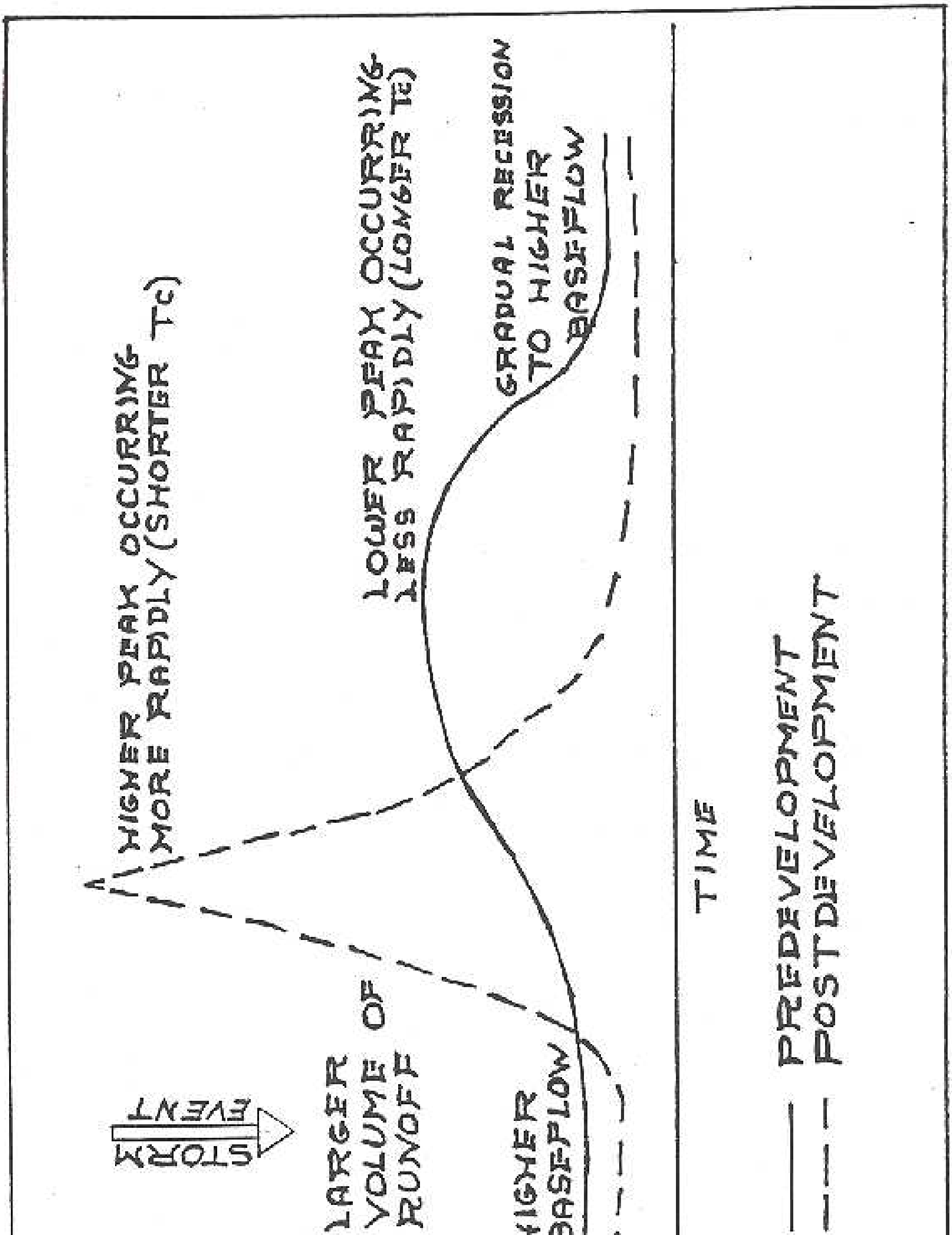
- For medium density residential areas, 50 percent of runoff was associated with rains less than 0.75 inches.

- A 100 year, 24 hour rain of 5.6 inches for Milwaukee could produce about 15 percent of the typical annual runoff volume, but only contributes about 0.15 percent of the average annual runoff volume, when amortized over 100 years.

- Typical 25 year design storms (4.4 inches in Milwaukee) produce about 12.5 percent of typical annual runoff volume but only about 0.5 percent of the average runoff volume.

An analysis, by the New Hampshire Department of Environmental Services, of precipitation records for the period 1978 to 1994, of the Concord, NH Weather Service Observatory showed that about one half the events were less than about 0.3 inches in rainfall, and about one half the rainfall volume were produced by events of one inch or less. A two year, 24 hour storm in Concord produces approximately 2.85 inches of rainfall. This magnitude storm is larger than approximately 98 percent of the events. Storms of this magnitude or less produce approximately 91 percent of the rainfall volume.

Figure 2.1: Changes in Watershed Hydrology as a Result of Urbanization



CONCLUSIONS AND SUMMARY

The two year-24 hour storm represents over 91 percent of the total rainfall and 98 percent of the measurable rainfall events. In addition control of the two year-24 hour storm is critical for control of streambank erosion. This would make the selection of the two year-24 hour storm as the storm to control for water quality purposes, a good selection for regulatory purposes.

Another consideration in design storm selection is the availability of design information. The SCS curve number method includes two year-24 hour information in its design manual and most rainfall frequency charts used in the Rational Method include two year storm events. Information on more frequent storms is not as readily available.

For flooding purposes, the 10-year storm event has proven satisfactory over the life of the New Hampshire Department of Environmental Service's Site Specific Program. This program permits large developments, regulating soil erosion control and stormwater management. If a larger but less frequent design storm is required by other jurisdictions, a multiple outlet design can readily accommodate all requirements.

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CHAPTER 3

VEGETATED FILTER STRIPS

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DEFINITION

Vegetated filter strips are areas of land with natural or planted vegetation designed to receive sheet runoff from upgradient development. They may be or resemble various natural environments such as meadows or riparian forests. Their primary function is to remove soil particles and nutrients from overland sheet flow before it reaches a surface water. The primary removal mechanisms are sedimentation and infiltration as the flow moves through the strip.

EFFECTIVENESS

Vegetated filter strips are effective in removing sediment and sediment laden pollutants from urban stormwater. They are effective only for sheet flow and provide little removals for concentrated flow. The United States Environmental Protection Agency (1993) lists the following percent removals for vegetated filter strips:

Pollutant	TSS	TP	TN	COD	Pb	Zn	Factors
Average	65	40	40	40	45	60	Runoff vol
Reported Range	20 - 80	0 - 95	0 - 70	0 - 80	20 - 90	30 - 90	Buffer length
Probable Range	40 - 90	30 - 80	20 - 60	--	30 - 80	20 - 50	Slope Soil infil
No. Values	7	4	3	2	3	3	Veg cover

To work properly, a filter strip must be: 1) equipped with some sort of level spreading device; 2) densely vegetated with a mix of erosion resistant plant species that effectively bind the soil; 3) graded to a uniform, even, and flat slope; and 4) be at least as long as the contributing runoff area (Schueler, 1987). Vegetated strips with shrubs and trees may remove more pollutants than grassed strips, as shrubs and trees absorb and retain more nutrients. To be effective, filter strips must be large in relation to the area being drained, relatively flat, and have a relatively low groundwater level (United States Environmental Protection Agency Region 5, 1992). The State of Rhode Island recommends against considering home lawns as part of a buffer strip, as lawns receive high pedestrian traffic and are extensively groomed (Rhode Island Department of Environmental Management, 1993)

PLANNING CONSIDERATIONS

The most important planning considerations for a filter strip include: the amount of runoff directed onto the strip, the slope of the strip, the need to maintain sheet flow across the strip, and the soil types in the strip.

The Rhode Island Department of Environmental Management (1993) recommends the following:

(a) Individual filter strips should only serve contributing areas less than 5 acres to reduce the potential for concentrated and erosive stormwater flows.

(b) Filter strips should be located on slopes of 5% or less to enhance filtering and infiltration of stormwater runoff.

(c) Filter strips should have topsoil composed of loamy sands, sandy loams, loam, or silt loam. Other soils with higher percentages of fine materials (e.g., silty clay loam, or sandy clay) are poorly suited for filter strips due to very slow infiltration rates and therefore are not suitable.

And the United States Environmental Protection Agency (1993) lists the following advantages and disadvantages:

ADVANTAGES

-Low maintenance
-Can be used as part of conveyance system
-Reduce particle pollutant loads
-Provides urban wildlife habitat
-Economical

DISADVANTAGES

-Often concentrates water , if poorly constructed, reducing effectiveness
-Variable ability to remove solubles
-Limited feasibility in highly urbanized areas
-Requires periodic maintenance and sediment removal

DESIGN CRITERIA

The filter strip should directly abut the impervious area or a level spreader should be constructed at the top of the strip to distribute the flow.

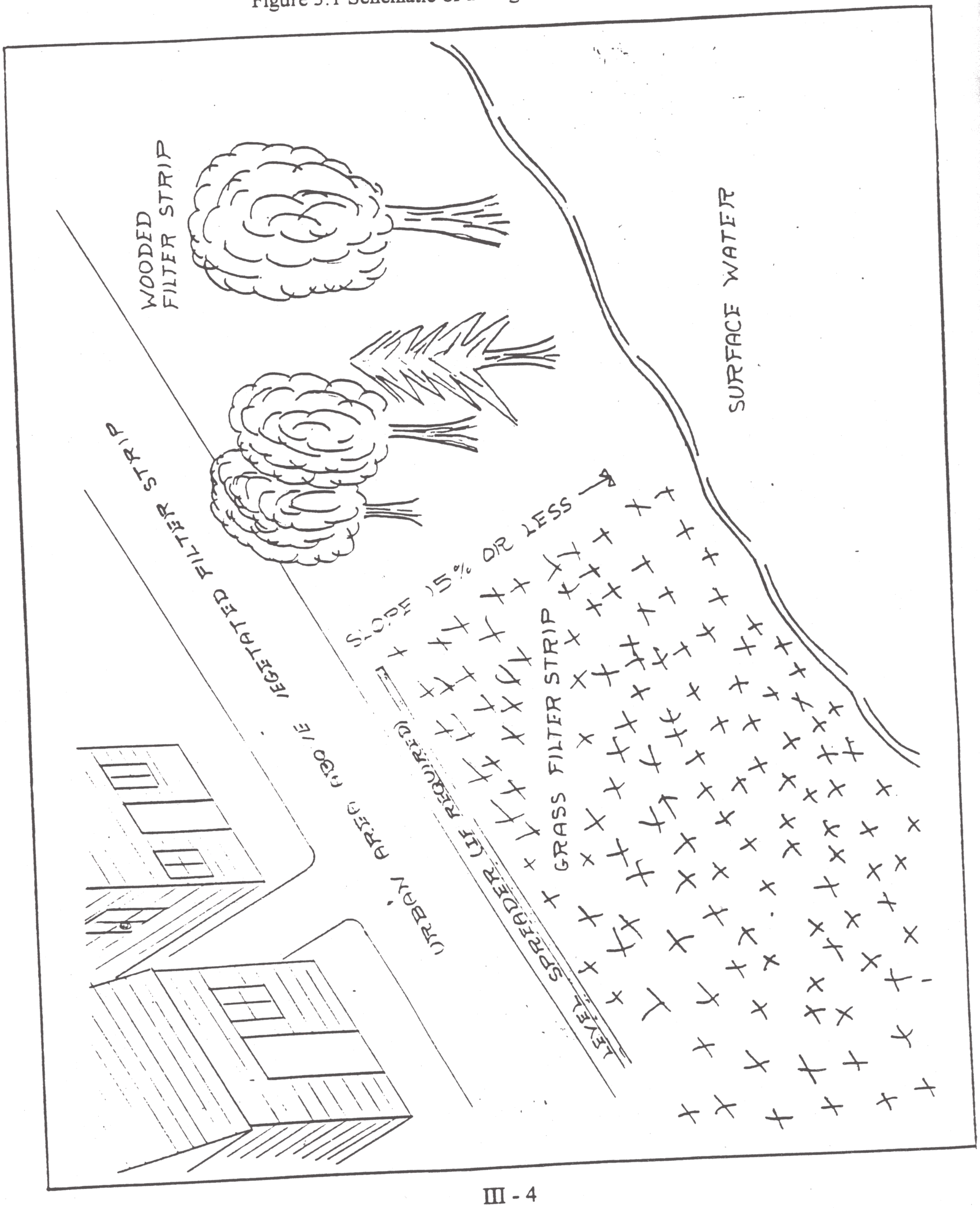
Wooded filter strips are preferred to grass strips. If an existing wooded strip does not exist, the grassed strip should be managed to allow woody vegetation to colonize the strip.

Flow to the filter strip should not exceed 0.5 cubic feet per second/foot of filter strip width.

Filter strip slope should not exceed 15 percent.

The minimum width of the filter strip should be 75 feet.

Figure 3.1 Schematic of a Vegetated Filter Strip



MAINTENANCE REQUIREMENTS

A properly designed and constructed filter strip should require little maintenance. It should be inspected frequently during the first year of operation and then annually thereafter. Large accumulations of sediments should be removed, and all gullies filled in and stabilized. Areas of bare soil should be immediately stabilized.

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CHAPTER 4

GRASSED SWALES

CHAPTER 4: GRASSED SWALES

DEFINITION

Grassed swales are shallow, vegetated, manmade ditches designed so that the bottom elevation is above the ground water table to allow runoff to infiltrate into the ground. The vegetation prevents erosion, filters sediment and provides some nutrient uptake (United States Environmental Protection Agency, 1993).

EFFECTIVENESS

Grassed swales have moderate ability to remove pollutants from stormwater. Unless the underlying soils allow for infiltration, swales have a limited capacity to remove soluble pollutants (New York Department of Environmental Conservation, 1992). Grassed swales are typically applied in single family residential developments and highway construction as an alternate to curb and gutter drainage systems (Schueler, 1987). Actual performance will be influenced by grass cover (extent, density, etc.), soil, runoff quality, and channel design. Research on removal effectiveness of grassed channels has shown the length should be at least 100 feet for adequate TSS removal (80%). This channel length will also remove about 60% of lead in runoff (United States Department of Transportation, 1988).

The United States Environmental Protection Agency (1993) lists the following percent removals for grassed swales:

Pollutant	TSS	TP	TN	COD	Pb	Zn	Factors
Average	60	20	10	25	70	60	Runoff vol
Reported Range	0 - 100	0 -100	0 - 40	25	3 - 100	50 - 60	Slope Soil infil
Probable Range	20 - 40	20 - 40	10 - 30	--	10 - 20	10 - 20	Veg cover
No. Values	10	8	4	1	10	7	Length Geom.

PLANNING CONSIDERATIONS

Grassed swales are most applicable in residential and other areas of low to moderate density, where the percentage of impervious area is small. The permeability or final infiltration rate of the soil will limit the utilization of swales for infiltration of runoff. The maximum allowable ponding time for swales is 24 hours (Maryland Department of the Environment, 1984). There should be a minimum distance of 2 feet between the bottom of the swale and the seasonal high water table, to provide for adequate infiltration. The minimum separation between the swale and any component of an individual sewage disposal system shall be as stated in the subsurface disposal system rules.

The United States Environmental Protection Agency, (1993) lists the following advantages and disadvantages for grassed swales:

ADVANTAGES	DISADVANTAGES
-Requires minimal land -Can be used as part of runoff conveyance system to provide pretreatment -Can provide sufficient runoff control to replace curb and gutter in single-family residential subdivisions and on highway medians -Economical	-Low pollutant removal rates -Leaching from culverts and fertilized lawns may actually increase the presence of trace metals and nutrients

DESIGN CRITERIA

Minimum length 100 feet.

Swale bottom slopes as flat as possible. swale can be terraced to achieve flat slope.

Swale side slopes no-steeper than 3:1 (h:v).

Maximum water velocity during a ten year storm of one foot per second (fps).

Maximum flow during the design storm of ten cubic feet per second (cfs).

A dense cover of water tolerant, erosion resistant grasses should be used.

Underlying soils should have sufficient percolation rate so that the swale will drain in twenty-four hours.

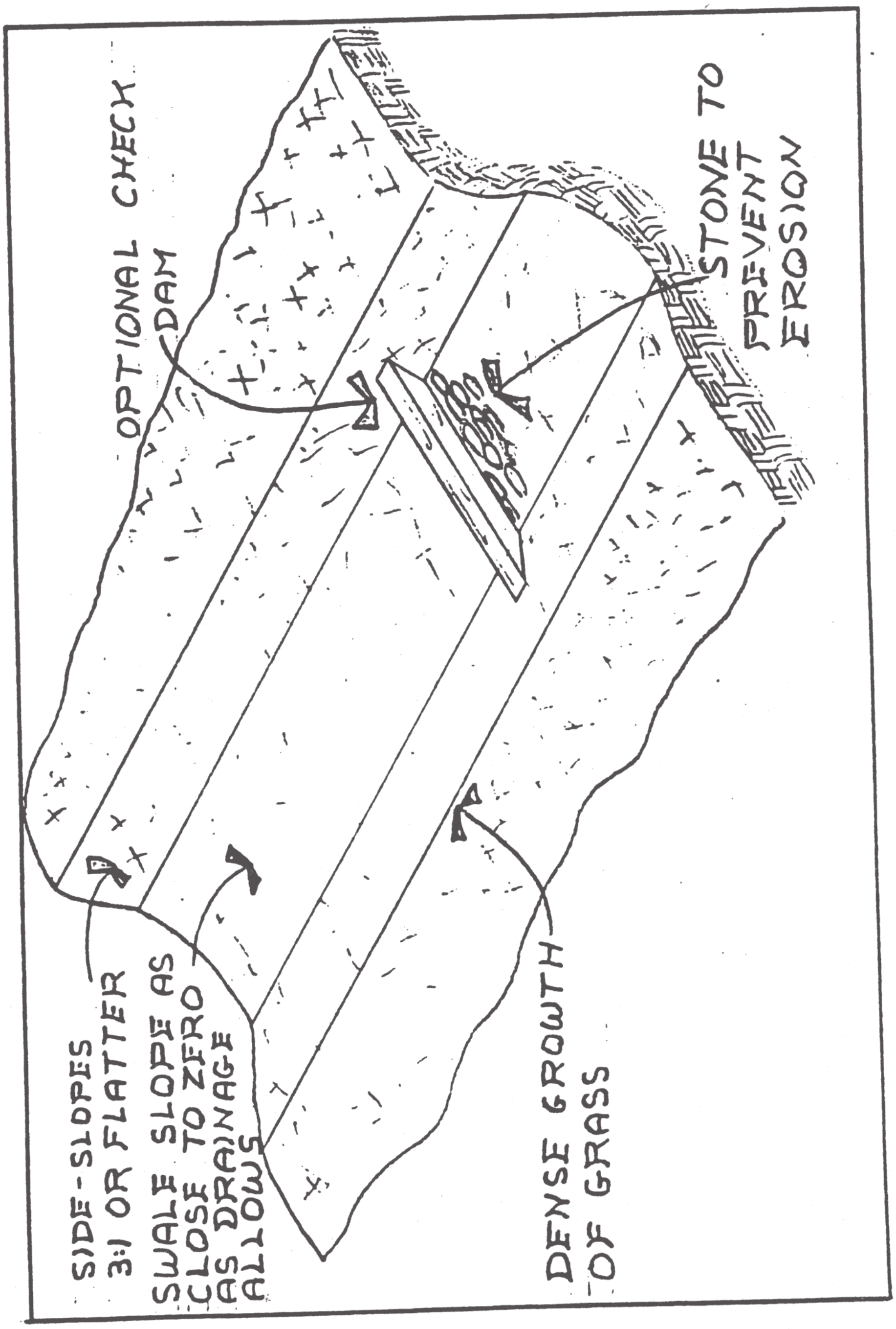
The bottom of the swale should be at least two feet above the seasonal high water table and bedrock.

Check dams are recommended to promote pollutant removals.

Erosion protection as required should be provided at the swale inlet and outlet.

Swale should be capable of conveying design storm of upstream drainage system without eroding.

Figure 4.1: Schematic of a Grassed Treatment Swale (adapted from Schueler, 1987)



MAINTENANCE REQUIREMENTS

Swales should be mowed at least once per year to prevent the establishment of woody vegetation.

Sediments should be removed as required, and swale reseeded if necessary.

Grass should not be mowed to less than three inches in height.

REFERENCES

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CHAPTER 5

EXTENDED DETENTION PONDS

CHAPTER 5: EXTENDED DETENTION PONDS

DEFINITION

An extended detention pond is a detention structure that is designed to temporarily hold storm water for up to 24 hours. The extended detention pond is normally dry between storm events, but may have a shallow marsh in the detention area. Unlike dry detention ponds, which only detain runoff long enough to reduce the peak rate of runoff, extended detention ponds detain stormwater runoff for a longer period of time to allow for settling of particulates.

EFFECTIVENESS

The United States Environmental Protection Agency (1993) lists the following percent removals for extended detention ponds:

Pollutant	TSS	TP	TN	COD	Pb	Zn	Factors
Average	45	25	30	20	50	20	Storage volume
Reported Range	5 - 90	10 - 55	20 - 60	0 - 40	25 - 65	(-40) - 65	Pond shape
Probable Range	70 - 90	10 - 60	20 - 60	30 - 40	20 - 60	40 - 60	Detention time
No. Values	6	6	4	5	4	5	

Schueler (1987) gives the following regarding the effectiveness of extended detention ponds:

Extending the detention time of dry or wet ponds is an effective, low cost means of removing particulate pollutants and controlling increases in downstream bank erosion. If stormwater is detained for 24 hours or more, as much as 90% removal of particulate pollutants is possible. However, extended detention only slightly reduces levels of soluble phosphorus and nitrogen found in urban runoff. Removal of these pollutants can be enhanced if the normally inundated area of the pond is managed as a shallow marsh or permanent pool.

Extended detention ponds significantly reduce the frequency of occurrence of erosive floods downstream, depending on the quantity of stormwater detained and the time over which it is released. Extended detention is extremely cost-effective, with construction costs seldom more than 10% above those reported for conventional dry ponds.

Pollutant Removal

Settling is the primary pollutant removal mechanism associated with extended detention. As such, the degree of removal is dependent on whether a given pollutant is in particulate or soluble form. Removal is likely to be quite high if a pollutant is particulate, whereas very limited removal can be expected for soluble pollutants. Unfortunately, some urban pollutants of greatest concern occur primarily in soluble form (e.g., nitrate and ortho-phosphorus). Removal of these soluble pollutants may be obtained if the lower stage of the extended detention pond is managed as a shallow wetland to utilize natural biological removal processes.

Additional Removal by Biological Means

Biological removal of soluble pollutants can be achieved by creating artificial wetlands in the lower stage of a dry extended detention pond. Marsh plants, algae and bacteria that grow on the plants and shallow, organic rich sediments can take up soluble forms of nutrients needed for their growth. Also, the marsh sediments are an excellent substrate for pollutant sorption.

PLANNING CONSIDERATIONS

Extended detention ponds are useful for developments that are not large enough to support a wet pond or created wetland. Wet ponds and created wetlands are preferred over extended detention ponds due to their higher removal efficiencies, particularly of soluble pollutants.

Extended detention ponds are typically composed of two stages: an upper stage that stays dry except for larger storms, and a lower stage designed for typical storms. Ponds can be provided with plunge pools at the inlet, a micropool at the outlet, and an adjustable reverse slope pipe as the outlet control device. The United States Environmental Protection Agency (1993) lists the following advantages and disadvantages for extended detention ponds:

ADVANTAGES

-Can provide peak flow control
-Possible to provide good particulate removal
-Can serve large developments
-Requires less capital cost and land area when compared to wet pond
-Does not generally release warm or anoxic water downstream

DISADVANTAGES

-Removal rates for soluble pollutants are quite low
-Not economical for drainage area less than 10 acres
-If not maintained, can be an eyesore, breed mosquitoes, and create undesirable odors

ADVANTAGES (cont.)

-Provides excellent protection for downstream channel erosion
-Can create valuable wetland and meadow habitat when properly landscaped

DESIGN CRITERIA

For adequate pollutant removal a minimum of 24 hours of extended detention must be provided for the design storm. Adjustments should be made in the outlet control device so that smaller runoff events are detained for at least six hours in the pond. Longer detention periods may be needed for streambank erosion control. And as a final check, the release rates should be evaluated to determine if they are erosive. The basin should be designed with a drawdown time of 24 to 40 hours.

A two stage design is recommended. The upper stage will be dry except during larger storm events, and the lower stage sized to be regularly inundated. The lower volume will be the site of the bulk of the pollutant removal, and will handle about 50-90% of the storms. A stone lined pilot channel should be constructed from the inlet to the lower stage. In general the basin should be wedge shaped with the inlet at the narrow end of the basin. The shape of the basin should have a length to width ratio of 3 or more. Dead storage areas should be avoided to allow for full utilization of the basin.

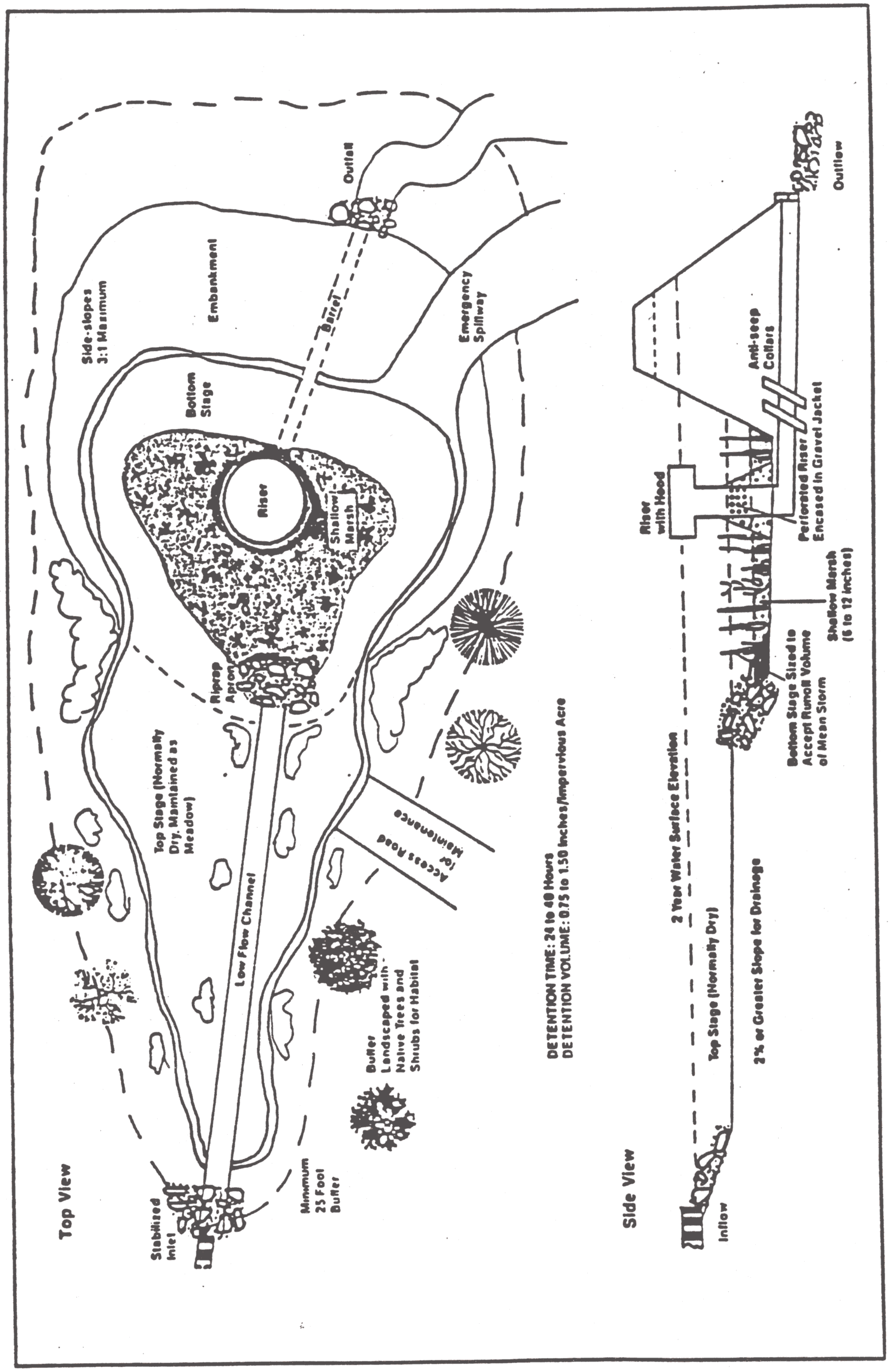
If a shallow marsh is to be utilized in the basin the depth should be not less than 6 inches and not more than 24 inches. The average depth of the temporary storage area should normally not exceed 10 feet. A shallow basin with a large surface area is preferable to a deeper one with a smaller surface area.

Side slopes of the extended detention pond should be no steeper that 3:1 (h:v) and no flatter than 20:1. Access and safety should be considered in determining proper basin side slopes.

A buffer of dense vegetation or fencing should be provided to limit access.

Pond berm may be classified as a dam and require approval by the Water Resources Division of DES

Figure 5.1: Schematic of Extended Detention Basin With Marsh (USDA-NRCS, 1992)



MAINTENANCE REQUIREMENTS

The embankment should be inspected annually to determine if rodent burrows, wet areas, or erosion of the fill are present. Trees and shrubs should be kept off the embankment and emergency spillway areas.

The vegetation should be mowed once per year to discourage woody growth. As much as possible vegetation should be managed without the aid of fertilizers.

Pipe inlets and outlets should be inspected annually and after major storm events.

Sediment should be continually checked in the basin and removed as necessary.

The structure should be inspected by a qualified professional on a periodic basis.

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CHAPTER 6

WET PONDS

CHAPTER 6: WET PONDS

DEFINITION

Wet ponds are designed to have a permanent pool of water, which prevents the resuspension of sediments in the pond from previous storm events. Microorganisms and plants in the permanent pool assist in biological uptake and degradation of pollutants. Additional storage is provided above the permanent pool to detain stormwater. Properly designed wet ponds can achieve both pollutant removal and peak discharge reduction.

EFFECTIVENESS

A properly sized and maintained wet pond can achieve a high removal rate of sediment, BOD, nutrients and trace metals. The high removal rate of wet ponds is primarily attributed to the permanent pool of water which provides for gravity settling of sediment, chemical flocculation, and biological uptake of pollutants.

Wet ponds can be effective in controlling post-development peak discharge rates to pre-development levels for desired design storms. Wet ponds, are not, however, effective in controlling post-development increases in total runoff volume from a project site.

Wet ponds are not without negative impacts. These include possible thermal impacts on cold water fisheries, potential safety hazards, occasional nuisance problems (e.g., odor, algae, and debris), and the eventual need for sediment removal. However, with proper maintenance the nuisance problems should be minimal. The primary limitations for the use of wet ponds are soils, terrain features and drainage area size. Soils must be either Hydrologic Group C or D, and have an infiltration rate that is less than 0.5 inches/hour (New York Department of Environmental Conservation, 1993). If the foregoing soil conditions can not be met then the pond may have to be lined or constructed into the water table.

The United States Environmental Protection Agency (1993) list the following percent removals of wet ponds:

Pollutant	TSS	TP	TN	COD	Pb	Zn	Factors
Average	60	45	35	40	75	60	Pool volume
Reported Range	(-30)-91	10 - 85	5 - 85	5 - 90	10 - 95	10 - 95	Pond shape
Probable Range	50 - 90	20 - 90	10 - 90	10 - 90	10 - 95	20 - 95	
No. Values	18	18	9	7	13	13	

The pollutant removal capability of two wet pond facilities were evaluated during the Washington, D.C. area NURP study. The wet ponds were found to be effective in removing particulate pollutants, with long-term average removal for the two ponds of 54% for sediment, 30% for chemical oxygen demand, 51% for zinc, 65% for lead, and approximately 20% for both organic nitrogen and phosphorus. In general, the removal of particulate pollutants in the wet ponds was very similar to that observed in extended detention ponds. Removal of organic materials was slightly lower in wet ponds in comparison to extended detention ponds, perhaps as a result of export of biomass and/or detritus from the ponds. The wet ponds were more effective in removing soluble nutrients with long term removal of 60% of the nitrate and over 80% of the soluble phosphorus recorded during the course of the study. Uptake by algae and aquatic plants was apparently responsible for the removal (Schueler, 1987).

Wet ponds monitored at other NURP projects followed the same pattern of pollutant removal observed in the Washington, D.C. area, with high sediment and trace metal removal, moderate removal of organic nutrients and COD, and apparently high removal of soluble nutrients. <u>The absolute level of pollutant removal was found to be primarily a function of the ratio of pond volume to watershed size.</u> Relatively undersized wet ponds had low and occasionally negative removal efficiencies, while moderate to large-sized ponds had correspondingly higher removal rates (Schueler, 1987).

PLANNING CONSIDERATIONS

Wet ponds require a drainage area of at least ten acres to generate sufficient water to keep the permanent pool full. As an alternative, the pond may intercept the ground water table. Wet ponds should not be constructed in natural wetlands or stream channels. Wet ponds should not receive continuous base flow as this will tend to keep the particulates in suspension and limit detention time needed for nutrient removal.

Wet ponds are not feasible in areas with shallow bedrock and highly permeable soils. In most cases a wet pond will consume less than 5% of the total watershed area. They do, however, require a relatively flat area at the bottom of the watershed.

The United States Environmental Protection Agency (1993) lists the following advantages and disadvantages for wet ponds:

ADVANTAGES

-Can provide peak flow control
-Can serve large developments; most-cost effective for larger, more intensively developed sites
-Enhances aesthetics and provides recreational benefits

DISADVANTAGES

-Not economical for drainage areas less than 10 acres
-Potential safety hazards if not properly maintained
-If not adequately maintained, can be an eyesore, breed mosquitoes, and create

ADVANTAGES (Continued)

-Little ground-water discharge
-Permanent pool in wet ponds helps to prevent scour and resuspension of sediments
-Provides moderate to high removal of both particulate and soluble stormwater pollutants

DISADVANTAGES (Continued)

undesirable odors
-Requires considerable space, which limits use in densely urbanized areas with expensive land and property values
-Not suitable for hydrologic soil groups "A" and "B" (SCS classification)
-With possible thermal discharge and oxygen depletion, may severely impact downstream aquatic life

DESIGN CRITERIA

Wet ponds should have an average depth of 3 to 10 feet in the permanent pool to prevent turbulent resuspension of the sediments.

The maximum depth should be no greater than 15 feet to avoid thermal stratification and associated release of phosphorus from the sediments.

Twenty five to thirty percent of the permanent pool surface area should be a maximum of 18 inches deep to promote wetland plant colonization along the pond edge.

The permanent pool should be designed to hold the volume of runoff generated by the design storm over the entire contributing watershed area.

Sufficient detention time is critical to the wet ponds effectiveness. Phosphorus is removed by sedimentation of fine particles and by biological activity.

Sediment storage should be provided in the permanent pool.

At least one foot of ice cover should be provided for.

The pond should be wedged shaped with the narrow end at the inlet and the permanent pool at the outlet end.

Ponds should have a length to width ratio of 3:1 of greater, with the inlet and outlet as far apart as possible.

Two or more ponds in a series provide the most effective treatment. The first pond experiences some mixing as incoming runoff meets still water, but water is pushed into subsequent ponds at a steady rate that discourages mixing and promotes plug flow. Multiple ponds also restrict wind-generated mixing over the total volume of the pond. Overflow outlets should be installed between ponds to ensure that water is released from the top of the pool.

The first pond, (for a multiple pond system) or the pond (for a single pond system), should be equipped with a sediment forebay equal to ten percent of the pond area, approximately one foot deep.

Ponds should have side slopes no steeper than 3:1 (h:v) nor flatter than 20:1.

Steep drop offs should be avoided.

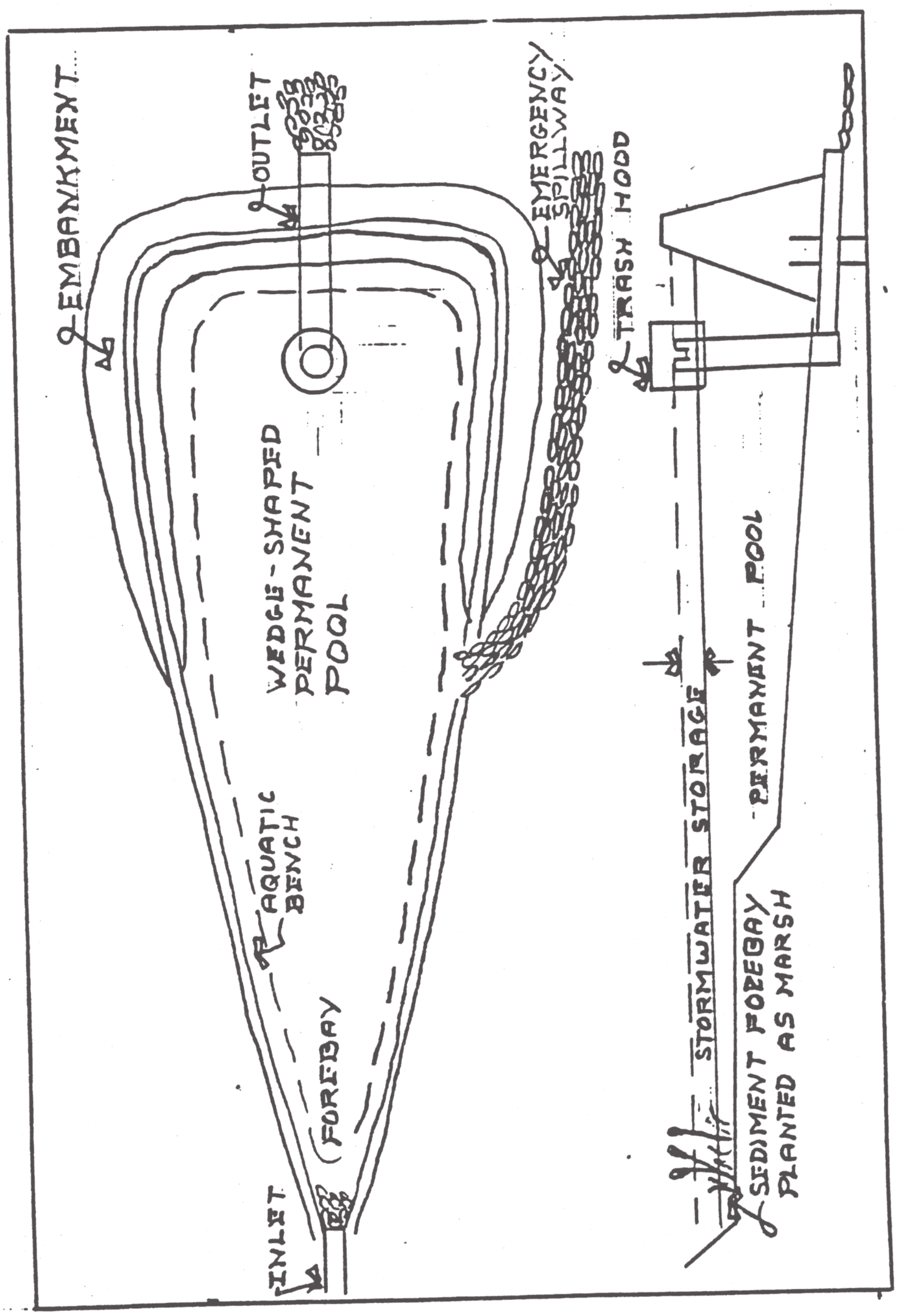
If steep drop offs can not be avoided then some type of restriction such as fencing or dense vegetation should be provided to restrict access.

The elevation of the pond's outlet should be a minimum of one foot above the seasonal high water table to prevent a continuous discharge of water from the pond and continuous flow of water into the pond.

Outflow from the pond should be to a stable channel.

Pond berms may be classified as a dam and require approval by the Water Resources Division of DES

Figure 6.1: Schematic of a wet pond



CHAPTER 7: CONSTRUCTED WETLANDS

DEFINITION

Constructed wetlands are engineered systems designed to simulate the water quality improvement functions of natural wetlands to treat and contain surface water runoff pollutants and decrease loadings to surface waters. Constructed urban runoff wetlands differ from artificial wetlands created to comply with mitigation requirements in that they do not replicate all of the ecological functions of natural wetlands (United States Environmental Protection Agency, 1993).

EFFECTIVENESS

Constructed wetlands are effective for removing a wide range of pollutants from urban runoff. The United States Environmental Protection Agency (1993) lists the following percent removals for constructed wetlands:

Pollutant	TSS	TP	TN	COD	Pb	Zn	Factors
Average	65	25	20	50	65	35	Storage volume
Reported Range	(-20)-100	(-120)-100	(-15)-40	20-80	30-95	(-30)-80	Deten. time
Probable Range	50-90	(-5)-80	0-40	---	30-95	___	Pool shape
No. Values	23	24	8	2	10	8	Biota season

Constructed wetlands remove pollutants through several mechanisms. The incoming runoff is slowed as it enters the wetland, allowing the settling of the suspended solids. Phosphorus and trace metals are frequently attached to particulate matter and are thus removed by sedimentation of these particles.

Constructed wetlands provide many sites for the adsorption of pollutants including the suspended sediments, plant matter, and bottom sediments and organic matter. The bottom sediments and organic matter can become a sink for pollutants as they build up over time. The sediments and organic mat are the only place available for long term storage of pollutants.

As the water flows through and around the vegetation some of the pollutants will be physically filtered out of the water. This filtration is not very effective in removing most pollutants from urban runoff except the larger floatables.

The surfaces on the various features in the wetland provide sites for micro-organisms to grow. These micro-organisms are effective in removing pollutants from the water. Kadlec (1994) has demonstrated that pollutant reductions are proportional to surface area not volume. The larger the surface area of the wetland the more plants and bottom area and corresponding increase in surfaces available for micro-organisms. This process is important in the removal of oxygen demanding substances and in the removal of nitrogen through nitrification/denitrification (Schueler, 1992). The principle function of vegetation in wetlands systems is to create additional environments for microbial populations (United States Environmental Protection Agency, Hammer, 1993).

The uptake by plants can be an important source of pollutant removal. The storage of pollutants in the live plants is only temporary however, a portion of the pollutants will be retained in the plants when they die and added to the organic matter on the wetland bottom. Thus a portion of the plant organic matter can be a source of long term storage of pollutants. The primary mechanism for long term removal of phosphorus is through plant cycling and soil accretion (Kadlec, 1994)

PLANNING CONSIDERATIONS

Constructed wetlands are complex ecosystems and require careful planning if they are to function correctly. The first consideration is the amount of available land area at the lower end of the watershed. Constructed wetlands should not be designed solely on surface area; for planning purposes 2% to 3% of the watershed area may be needed for the constructed wetland.

After determining the availability of sufficient land area, the availability of sufficient water is the most critical item. Because of the nature of the watersheds these wetlands will be serving, the water availability will be variable and not completely reliable. The urban area above the constructed wetland will be subject to all the factors discussed in chapter 2, particularly the high peak flows and low base flows. Wetland construction efforts often fail when a plan fails to provide hydrologic support of the proposed structure and functions. Plans should include calculations indicating the amount of water required to support the planned wetland plant community. These calculations should indicate the major input and output components of a hydrologic budget (Pierce, 1993).

Wetlands can provide stormwater detention and reductions in peak flow. The ability of the downstream water body to accept increases in runoff and the impact of the development must be evaluated. If the wetland will provide for stormwater detention, the stormwater storage must be in addition to the normal water quality volume provided in the wetland. The water depth and duration of inundation above the normal water quality volume are critical factors in selecting vegetation.

Finally, planning must consider the other functions of the wetland. Will it be an amenity to the site providing wildlife, recreational, and other benefits? The types of vegetation and water regimes need to be planned in advanced.

Schueler (1992) breaks constructed wetlands into several categories, four of which are of interest:

Design 1: Shallow Marsh System. The Shallow marsh design has a large surface area, and requires a reliable source of baseflow or groundwater supply to maintain the desired water elevations to support emergent wetland plants. Consequently, the shallow marsh system requires a lot of space and a sizeable contributing watershed area to support the shallow permanent pool.

Design 2: Pond/Wetland System. The pond/wetland design utilizes two separate cells for stormwater treatment. The first cell is a wet pond and the second cell is a shallow marsh. The multiple functions of the wetpond are to trap sediments, reduce incoming runoff velocity, and to remove pollutants. The pond/wetland system consumes less space than the shallow marsh, because the bulk of the treatment is provided by the deeper pool rather than the shallow marsh.

Design 3: Extended Detention Wetland. In extended detention wetlands, extra storage is created above the shallow marsh by temporary detention of runoff. The extended detention feature enables the wetland to consume less space, as temporary vertical storage is partially substituted for shallow marsh storage. A new growing zone is created along the gentle side-slopes of extended detention wetlands that extends from the normal pool elevation to the maximum extended detention water surface elevation.

Design 4: Pocket Wetlands. Pocket wetlands are adapted to serve smaller sites from one to ten acres in size. Because of their small drainage areas, pocket wetlands usually do not have a reliable source of baseflow, and therefore exhibit widely fluctuating water levels. In most cases, water levels in the wetland are supported by excavating down to the water table. In drier areas, the pocket wetland is supported only by stormwater runoff, and during extended periods of dry weather, will not have a shallow pool at all (only saturated soils). Due to their small size and fluctuating water levels, pocket wetlands often have low plant diversity and poor wildlife habitat value.

DESIGN CRITERIA

The design of wetlands for treating urban runoff is a new field without a lot of generally accepted design standards. The following standards are minimum standards, and are intended to give direction without being too restrictive as new technology is developed. It should also be understood that these standards are not all inclusive regarding the design of constructed wetlands, but are intended to address those areas unique to urban runoff. The designer must have a general knowledge of wetlands creation including soils, hydrology, and vegetation.

The volume of storage capacity below the outlet (water quality volume) should be equal to a one inch of rainfall over the tributary area.

Surface area of the wetland should be a minimum of 2% to 3% of the watershed area.

The wetland should have two micropools comprising between 20% and 40% of the total wetland water quality volume.

The first micropool to be a sediment forebay and contain 10% of the total wetland water quality volume.

The second micropool to be an afterbay and contain 10% to 30% of the total wetland water quality volume.

The micropools should be a minimum of 3 feet and a maximum of 6 feet deep

The wetland between the two micropools should be a marsh with variable depth between 6 inches and 2 feet deep.

The outlet of the sediment forebay to the marsh should be designed to evenly distribute the flow over the marsh.

The length of the basin should be at least twice the width.

Inlets and outlets should be at opposite ends of the wetland, if this can not be accommodated, then baffle islands should be constructed to maximize the flow path.

A hydrologic budget should be prepared for the design demonstrating that sufficient water is available to maintain the wetland, and that the wetland will not be inundated with an excess of water.

The marsh portion of the wetland should be designed with a dense, well distributed stand of vegetation such as cattails or bulrushes.

If the wetland is also utilized for stormwater detention, it should be designed based upon extended detention.

Maximum sideslopes should be 2:1. provision must be made for access by maintenance equipment.

The constructed wetlands should have a freeboard of at least one foot.

The outlet should be a reverse slope pipe or other device which will allow water from below the surface to outlet, thus trapping floatable solids.

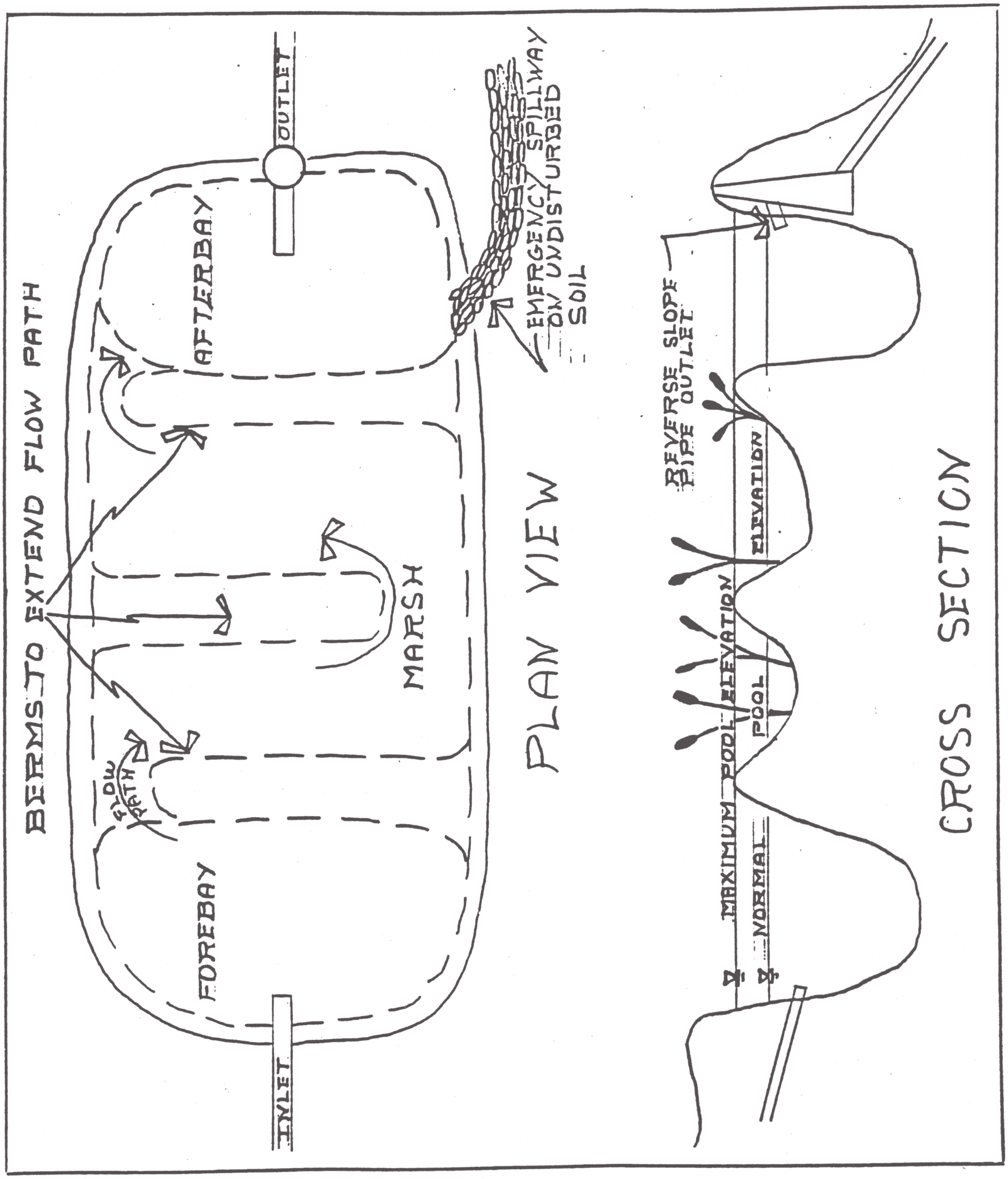
Outlet should be installed with suitable anti-seep collars.

Inlet area should be protected from erosion with suitable riprap or the inlet enter the pool below the water surface.

A buffer of dense vegetation or fencing should be provided to limit access

Wetland berms may be classified as a dam and require approval by the Water Resources Division of DES

Figure 7.1: Schematic of a Constructed Wetland



CHAPTER 8

INFILTRATION PRACTICES

CHAPTER 8: INFILTRATION PRACTICES

DEFINITION

Infiltration practices are designed to infiltrate surface runoff into the ground. These devices include both infiltration trenches and infiltration ponds. An infiltration trench is a subsurface trench filled with stone to which runoff is either piped directly or flows overland. An infiltration basin is an open area to which the runoff is discharged and allowed to pond while infiltrating through the sides and bottom of the basin.

EFFECTIVENESS

Infiltration practices have a lot to recommend them, as they can more closely achieve the goal of no change from the predevelopment to post-development runoff hydrology than other methods. By infiltrating the runoff, the pollutants will be removed in the soil and the stream hydrology maintained. However, infiltration practices have a major drawback, their high maintenance requirements. Studies by the Maryland Department of the Environment in 1986 and 1990 revealed that of those surveyed 48% of the basins and 80% of the trenches were functioning as designed in 1986 and only 38% of the basins and 53% of the trenches were functioning as designed in 1990 (1986 & 1990). The 1990 survey was a followup of the 1986 survey. These surveys are of importance as Maryland has been a leader in stormwater management in general and stormwater infiltration in particular. The Maine Department of Environmental Protection (1989) recommends the selection of infiltration practices only after exhausting other alternatives.

The United States Environmental Protection Agency (1993) lists the following percent removals for infiltration devices:

Infiltration trenches

Pollutant	TSS	TP	TN	COD	Pb	Zn	Factors
Average	75	60	55	65	65	65	Soil perc rates
Reported range	45 - 100	40 - 100	(-10)-100	45 - 100	45 - 100	45 - 100	Storage volume
Probable range SCS Group A Group B	60 -100 50 - 90	60 - 100 50 - 90	60 - 100 50 - 90	60 - 100 50 - 90	60 - 100 50 - 90	60 - 100 50 - 90	Trench surface area
No. Values	9	9	9	4	4	4	

Infiltration basins

Pollutant	TSS	TP	TN	COD	Pb	Zn	Factors
Average	75	65	60	65	65	65	Soil perc rates
Reported range	45 - 100	45 - 100	45 - 100	45 - 100	45 - 100	45 - 100	Storage volume
Probable range SCS soil Group A Group B	60 - 100 50 - 80	60 - 100 50 - 80	60 - 100 50 - 80	60 - 100 50 - 80	60 - 100 50 - 80	60 - 100 50 - 80	Basin surface area
No. Values	7	7	7	4	4	4	

PLANNING CONSIDERATIONS

Infiltration devices should only be selected after all other methods of providing stormwater treatment have been evaluated and eliminated. Infiltration devices should be used on small watersheds (up to 25 acres) that do not have a permanent source of base flow and are not subject to erosion.

The infiltration device should be constructed in soils with a percolation rate not less than 0.5 inches per hour. Depth to seasonal high ground water and bedrock should be at least 4 feet from the bottom of the device.

Infiltration devices should be preceded by a pretreatment device such as vegetated filter strip, treatment swale, or water quality inlet. Infiltration devices should not be used in well head protection areas. Infiltration devices should only be designed for residential and retail type commercial developments. They should not be utilized at industrial sites or petroleum storage or dispensing sites.

Infiltration devices should be capable of infiltrating the design storm within 72 hours. Consideration of frozen ground conditions in both the contributing watershed and infiltration basin must be made during the design. The infiltration device should not have runoff directed to it until the contributing watershed is stabilized. As the failure rate is high, provisions must be made to handle the stormwater runoff as though the infiltration device is non-existent.

The United States Environmental Protection Agency (1993) lists the following advantages and disadvantages:

Infiltration Trenches

ADVANTAGES

-Provides groundwater recharge
-Can serve small drainage areas
-Can fit in medians, perimeters, and other unused areas of the development site
-Helps replicate predevelopment hydrology, increases dry weather baseflow, and reduces bankfull flooding frequency

DISADVANTAGES

-Possible risk of contaminating ground water
-Only feasible where soil is permeable and there is sufficient depth to rock and water table
-High failure rate
-If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors
-Regular maintenance activities cannot prevent rapid clogging of infiltration basins

Infiltration Basins

ADVANTAGES

-Provides ground water recharge
-Can serve large developments
-High removal capability for particulate pollutants and moderate removal for soluble pollutants
-When basin works, it can replicate predevelopment hydrology more closely than other options
-Basins provide more habitat value than other infiltration systems

DISADVANTAGES

-Possible risk of contaminating ground water
-Only feasible where soil is permeable and there is sufficient depth to rock and water table
-Since not as visible as other BMP's less likely to be maintained by residents
-Requires significant maintenance
-High failure rate

DESIGN CRITERIA

I. INFILTRATION TRENCHES

An infiltration trench should range from 2 to 10 feet in stone reservoir depth.

The trench system storage volume should be equivalent to the volume of runoff generated by a 2 year-24 hour storm, less expected infiltration.

The maximum storage time(time to drain) should be 72 hours.

The depth to seasonal high water table and bedrock should be at least 4 feet below the bottom of the trench.

The backfill material should consist of a clean aggregate material with a maximum diameter of 3" and a minimum diameter of 1-1/2". Void spaces in these aggregates is assumed to be in the range of 30 to 40%. The aggregate material should be completely surrounded with a geotextile fabric.

An observation well should be installed in every infiltration trench.

All trenches should be excavated using light equipment, taking care not to compact the underlying soils.

A trench can also be used under a grassed swale to improve the performance of the swale. A trench with a grassed surface should consist of at least one foot of soil above the stone.

II. INFILTRATION BASINS

The floor of the basin should be graded as flat as possible to permit uniform ponding and exfiltration. Low spots and depressions should be leveled out. Side-slopes leading to the floor should have a maximum slope of 3:1(h:v) to allow for easier mowing and better bank stabilization.

All basins should have sediment forebays or riprap aprons that dissipate the velocity of incoming runoff, spread out the flow and trap sediments before they reach the basin floor.

The storm drain inlet pipe (or channel) leading to the basin should discharge at the same invert elevation as the basin floor. Similarly, the low flow orifice in an infiltration/detention basin should be set at the same elevation as the basin floor, to prevent baseflow from ponding and thus impeding the function of the basin.

The floor of the basin should be stabilized by a dense turf of water tolerant reed canary grass or tall fescue, immediately after basin construction. The grass turf promotes better infiltration, pollutant filtering, and prevents erosion of the basin floor.

The basin should be excavated with light equipment with tracks or over-sized tires to minimize compaction of the underlying soils. After the basin is excavated to the final design elevation, the floor should be deeply tilled with a rotary tiller or disc harrow to restore infiltration rates, followed by a pass with a leveling drag. Vegetation should be established immediately. The riser, embankment, and emergency spillway should be sized and constructed to the normal specifications for conventional ponds.

A minimum buffer of 25 feet from the edge of the basin to the nearest adjacent lot should be reserved. A landscaping plan should be prepared for the basin buffer that emphasizes low maintenance, water tolerant, native plant species that provide food and cover for wildlife, and when necessary, can act as a screen.

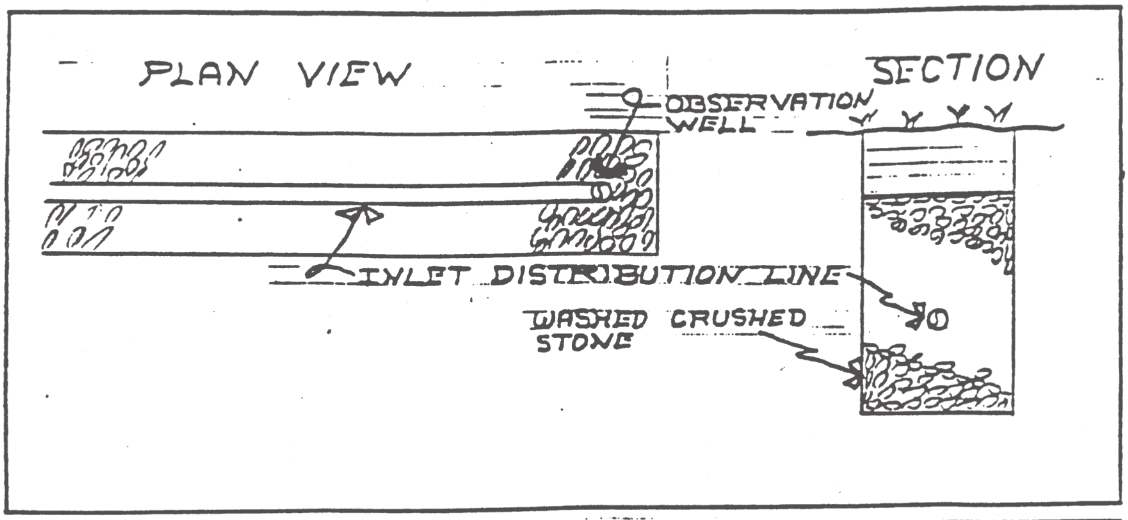
Basin should be equipped with an emergency spillway.

Adequate access to the basin floor should be provided from a public or private right-of-way that can withstand light equipment. Such access should be at least 12 feet wide, and should not cross the emergency spillway.

The basin storage volume should be equivalent to the volume of runoff generated by a 2 year-24 hour storm, less expected infiltration.

Fencing or dense vegetation should be provided to restrict access

Figure 8.1: Schematic of an Infiltration Trench



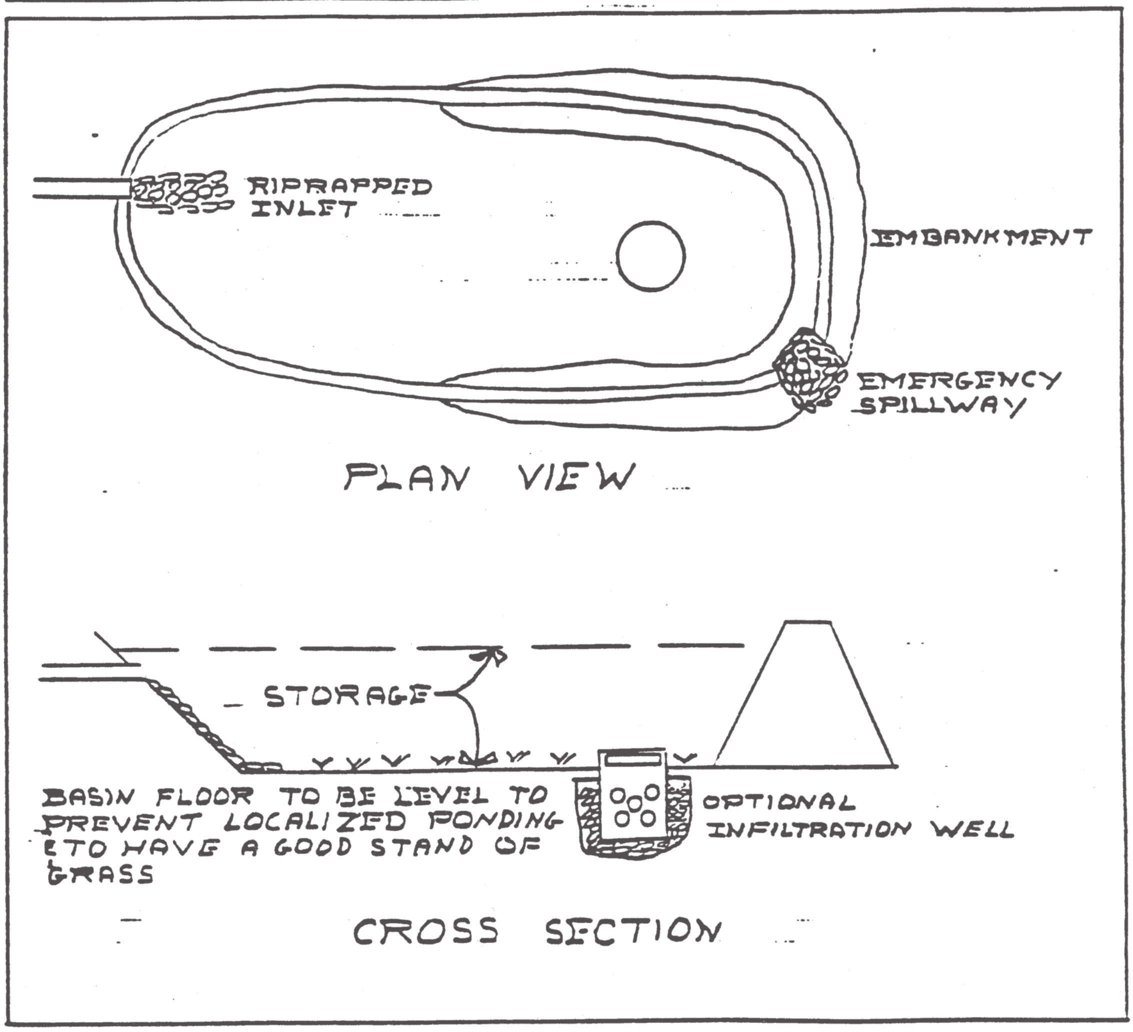


Figure 8.2: Schematic of an Infiltration Basin

MAINTENANCE REQUIREMENTS

Maintenance of infiltration practices is as or more important than maintenance on any other practice. Without adequate maintenance these systems not only fail to meet their design objective but may and have resulted in flooding and associated property damage.

Maintenance responsibilities should be clearly vested, and funds reserved for both routine and non-routine maintenance tasks.

The change in standing water depth above the basin floor or trench bottom over time should be checked after each major storm in the first few months after construction to monitor exfiltration rates. Similar tests should be conducted annually to gage the degree of surface clogging that may occur over the years, and to help in scheduling restorative maintenance. These annual inspections should include removal of accumulated sediments; inspection and maintenance of pretreatment devices; maintenance of a dense grass buffer strip for surface trenches; and partial or total reconstruction in the event of clogging.

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CHAPTER 9

WATER QUALITY INLETS

CHAPTER 9: WATER QUALITY INLETS

DEFINITION

Water quality inlets (WQI) are also known as oil and grit separators. They are underground, multi-chambered tanks designed to remove sediments and to a lesser degree floatable solids.

EFFECTIVENESS

Under current designs, WQI can only store a small fraction of the two year 24-hour design storm volume. Since runoff is only briefly retained in the inlets, only moderate removal of coarse sediment, oil/grease, and debris can be expected. Even more limited removal is likely for fine-grained particulate pollutants such as silt, clay and associated trace metals and nutrients. Soluble pollutants probably pass through inlets without modification. WQI typically serve parking lots one acre or less in size, and are particularly appropriate for sites that are expected to receive a great deal of vehicular traffic or petroleum inputs (e.g., gas stations, roads, loading areas). Routine maintenance costs are high since the inlets must be cleaned out at least twice a year to remove trapped pollutants and to ensure proper inlet function.

Advantages of the WQI lie in their unobtrusiveness, compatibility with the storm drain network, easy access, and capability to pretreat runoff before it enters infiltration BMPs. Disadvantages include their limited stormwater and pollutant removal capabilities, the need for frequent clean-outs (which can not always be assured), and possible difficulties in disposing of accumulated sediments (Schueler, 1987).

The United States Environmental Protection Agency (1993) lists the following percent removals for water quality inlets:

Pollutant	TSS	TP	TN	COD	Pb	Zn	Factors
Average	35	5	20	5	15	5	Maint.
Reported Range	0 - 95	5 - 10	5 - 55	5 - 10	10 - 25	5 - 10	Sed. storage
Probable Range	10 - 25	5 - 10	5 - 10	5 - 10	10 - 25	5 - 10	
No. Values	3	1	2	1	2	1	

A number of factors inherent in the typical three-chamber design serve to limit pollutant removal.

1. The limited amount of wet storage provided by the WQI. A standard sized three-chamber WQI has about 0.12 inches of runoff per acre in the permanent pool of the first and second chambers.

2. Since WQIs serve such small areas, and have such a small capacity, runoff passes through them very quickly. The average detention time of runoff during most storms will seldom exceed an hour, and in many cases, may be measured in minutes.

3. Pollutants deposited within a chamber can only be permanently removed during cleanouts. Sediment deposited during smaller storms may be resuspended and scoured out during the next large storm (Schueler, 1987).

PLANNING CONSIDERATIONS

WQIs are to be used after exhausting other alternatives. They are typically used on small (less than an acre) watersheds. WQIs may be used prior to infiltration devices and on existing developed sites. They may be used on larger watersheds by utilizing a number of them on the drainage network. The United States Environmental Protection Agency (1993) lists the following advantages and disadvantages:

ADVANTAGES

-Captures coarse-grained sediments and some hydrocarbons
-Requires minimal land area
-Flexibility to retrofit existing small drainage areas and applicable to most urban areas
-Shows some capacity to trap trash, debris, and other floatables
-Can be adapted to all regions of the country

DISADVANTAGES

-Not feasible for drainage areas greater than one acre
-Minimal nutrient and organic matter removal
-Not effective as water quality control for intense storms
-Concern exists over the pollutant toxicity of of trapped residuals
-Requires high maintenance

DESIGN CRITERIA

WQI should be a three chamber design with the first and second chambers having a combined volume equal to 400 cubic feet per contributing impervious acre. In addition, the minimum depth of the permanent pool in these chambers will be no less than 5 feet.

The inflow pipe should be constructed and sized to pass the water quality flow rate into the WQI. All additional flows should be passed through another pipe into a detention facility of sufficient capacity to meet applicable peak discharge control requirements.

When the structure length exceeds twelve feet the first two chambers are proportioned so that the first chamber (grit) is 2/3 of the length and the second chamber (oil) is 1/3 of the length.

To facilitate cleanouts, access to each chamber should be provided by means of a separate manhole.

The walls separating the chambers must be water tight and only allow passage of stormwater through the design ports or pipes. There shall be no additional vents or passageways within the walls.

All hardware and piping within the tank should be galvanized, corrosion resistant, or stainless steel. Pipes made of PVC are acceptable and in some applications may be preferable, however, these pipes must be constructed of schedule 40 or greater.

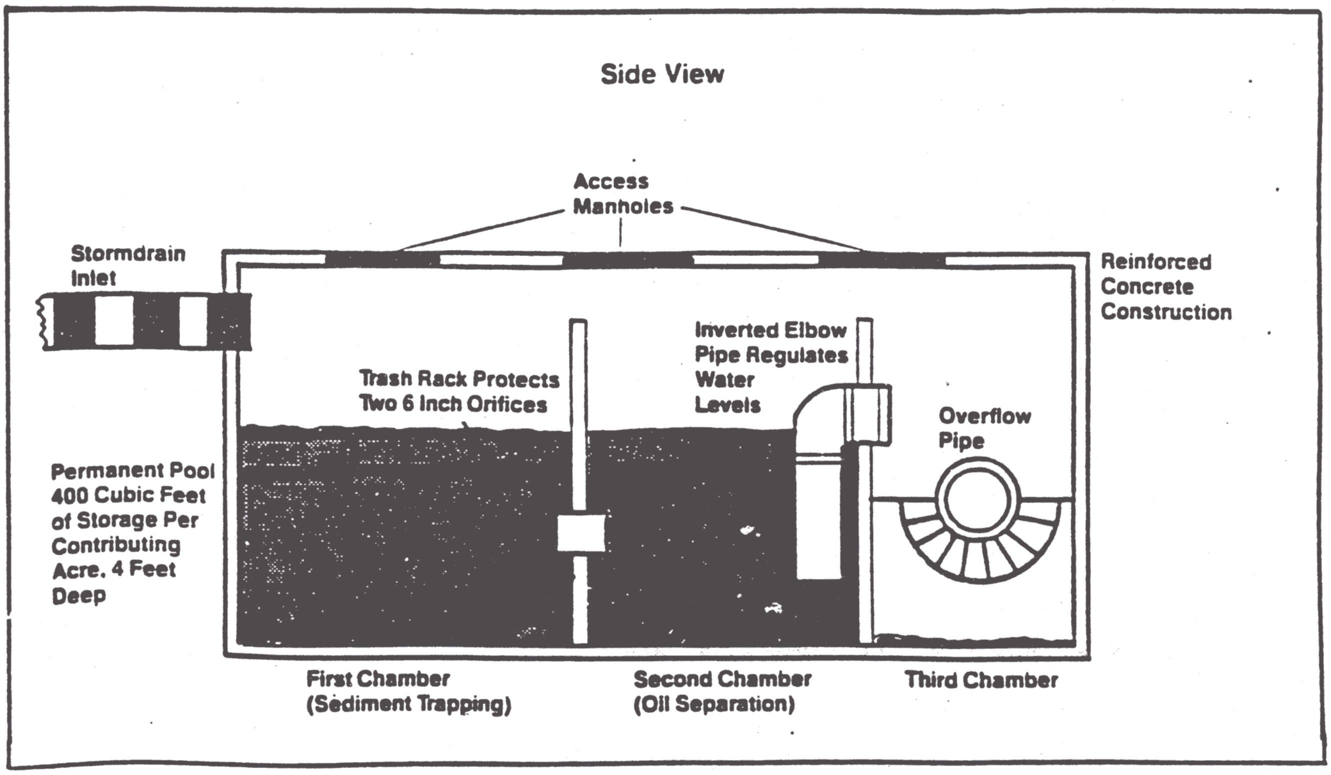
MAINTENANCE REQUIREMENTS

WQI inlets should be inspected monthly to determine depth of accumulated sediment.

Accumulated sediment should be cleaned out from inlets at least twice per year or more frequently if monthly inspections indicate a need. This can be done by vacuum pumping or siphoning of the permanent pool, and manually removing the sediments.

Accumulated deposits should be properly disposed of. Runoff in the inlet can be siphoned over to an adjacent grass filter strip, or transported to a sanitary sewer line and routed to a treatment plant.

Figure 9.1: Schematic of a Water Quality Inlet, Montgomery County, MD, Three Chamber Design, (Schueler, 1987)



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APPENDIX A

SITE SPECIFIC PROGRAM FACT SHEETS

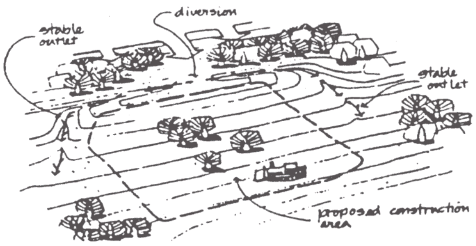
ENVIRONMENTAL
Fact Sheet

NEW HAMPSHIRE
DEPARTMENT OF
Environmental
Services

6 Hazen Drive, Concord, New Hampshire 03301 · (603) 271-3503 · www.state.nh.us/des

WD-WQE-2 1997

FEES FOR ALTERATION OF TERRAIN PERMITS (SITE SPECIFIC)



Fees for Site Specific permits issued in accordance with NH RSA 485-A:17 have been required since May 1989. This requirement was amended by passage of NH RSA 483-B, The Comprehensive Shoreland Protection Act in 1991. This act established a protected shoreland within 250 feet of public waters.

Specifically, Site Specific permits and therefore fees are required for projects which will disturb an area of 100,000 square feet or greater in all locations. In addition, projects within the protected shoreland which will disturb an area of at least 50,000 square feet also require Site Specific permits and therefore fees.

It should be noted that the fees are in even $100 increments. The fee for a project disturbing from 50,000 to 199,999 square feet within the protected shoreland and from 100,000 to 199,999 square feet outside the protected shoreland is $100, while the fee for disturbing 200,000 to 299,999 square feet at all locations is $200. In practice, the area is measured as follows:

1. For a single family home subdivision in which the lot development will not be carried out at the same time as roadway construction, (i.e., the roadway and other work within the roadway right-of-way will be completed and stabilized prior to grading the lots), the only item considered in calculating the disturbed area is the roadway. For example, for a 50 foot right-of-way, 1000 linear feet of roadway would create an area of disturbance of 50,000 square feet and 2000 linear feet of roadway would create an area of disturbance of 100,000 square feet.

2. For other types of development and for earth removal operations, the contiguous earth disturbance would include such items as building area, parking, driveways, roadways, utility construction, landscaping and borrow areas.

For further information, contact the DES Water Division, Wastewater Engineering Bureau, at (603) 271-3503.

ENVIRONMENTAL
Fact Sheet

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

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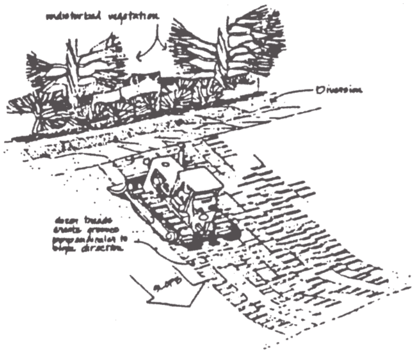
WD-WQE-3 1997

ALTERATION OF TERRAIN PERMITS (SITE SPECIFIC)

When Are They Required?



Developers, municipal officials and private citizens frequently inquire about the need for an RSA 485-A:17 (formerly 149:8-a) Site Specific permit for a particular project. These Alteration-of-Terrain permits are designed to protect New Hampshire surface waters by minimizing soil erosion and controlling stormwater runoff.

The N.H. Department of Environmental Services, Water Division issues these permits under N.H. Administrative Rules Env-Ws 415. These rules state in part:

Permit Required. A permit shall be obtained from the division prior to commencing any of the following activities:

> 415.03(b) Construction, earth moving or other significant alteration of the characteristics of the terrain...when a contiguous area of 50,000 square feet or more if within the protected shoreland as defined by RSA 483-B or 100,000 square feet or more in all other areas will be disturbed.

This Requirement is applied by the Division in the following ways:

1. For a single family subdivision in which the lot development will not be carried out at the same time as roadway construction, (i.e., the roadway and other work within the roadway right-of-way will be completed and stabilized prior to grading the lots), the only item considered in calculation of disturbed area is the roadway. For example, for a 50 foot right-of-way, 2000 linear feet of roadway would create an area of disturbance of 100,000 square feet, thus requiring a Site Specific permit.

2. For other types of developments and earth removal operations, a contiguous earth disturbance of 100,000 square feet including building area, parking, driveways, roadways, utility construction, landscaping and borrow areas would require a Site Specific permit.

3. For earth removal operations in existence on the effective date of the regulations, May 4, 1981, the "footprint" of the area of disturbance at that time is considered to be grandfathered, but any contiguous disturbance of 100,000 square feet or more outside that footprint requires a Site Specific permit.

4. In addition to the above, RSA 483-B, the "Comprehensive Shoreland Protection Act," requires that any person intending to conduct an activity within the protected shoreland resulting in a contiguous disturbed area exceeding 50,000 square feet to first obtain a permit pursuant to RSA 485-A:17. The protected shoreland is defined by the act as all land located within 250 feet of the reference line of public waters.

For further information, contact the DES Water Division, Wastewater Engineering Bureau, at (603) 271-3503.